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Project Summary

Insituform and Other Sewer Rehabilitation Techniques

Michael R. Olson

Four methods were examined for rehabilitating defective sanitary sewers with respect to (1) logistic problems, (2) equipment and labor required by each, (3) the environmental impact as related to noise, air, and water pollution, (4) the social impacts, including public inconveniences from traffic disruption, utility relocation, and the temporary disruption of sanitary service, (5) economic parameters, including adjusted cost comparisons and the cost effectiveness of each alternative, (6) the effectiveness of the technique in reducing mainline infiltration, (7) durability of the products, and (8) before-and-after flow properties of the rehabilitated sections. The four methods studied were Insituform* lining, test-and-seal, point repair, and conventional sliplining. The study emphasizes Insituform lining, especially as installed in Hagerstown, Maryland, and it includes discussion of installation procedures and problems, product limitations, spatial requirements of the equipment, and safety hazards and procedures.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The public works industry shares a widespread concern about the progressively deteriorating condition of sewer collection systems across the nation. Larger and larger wastewater treatment plants are being designed and constructed every day, in many cases to treat flows that result from the infiltration and inflow (I/I) of stormwater into the sanitary sewer system. Engineers are increasingly hesitant to attack the I/I problems existing within collection systems because of the uncertain results of any anticipated sewer rehabilitation program. Less risk is involved in designing an oversized treatment plant to accommodate extraneous flows than in attempting to control and limit these flows. However, the engineer can be doing a disservice to his client by overlooking some cost effective measures of eliminating extraneous flows in the sewer network. Engineers, municipal employees and officials, and regulatory agencies must pay increased attention to the collection system. This study attempts to present methods by which substandard conduits can be repaired, and it compares the advantages and disadvantages of each alternative.

The four sewer rehabilitation methods included in this study were Insituform lining, test-and-seal, point repair, and conventional sliplining. Insituform lining is a new technique in which a thermosetting-polymer-soaked bag is blown into the existing sewer line, usually with water pressure. Hot water or steam is then used to cure the polymer producing a rigid liner conforming to the original pipe. Because the liner offers structural stability, it can be used to rehabilitate badly deteriorated sewers. The test-and-seal procedure makes use of chemical grout that is injected into imperfections in the pipe. Equipment has been developed for testing and sealing in one operation. This method cannot be used with badly deteriorated sewers. Point repair refers to replacement of pipe where pipe condition is too poor to

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use

permit application of any less complete rehabilitation procedure. Sliplining involves the insertion of a slightly smaller diameter pipe inside the original pipe. The availability of slightly flexible plastic pipe allows long lengths of sewer to be relined in one operation. This method is applicable to badly deteriorated sewers so long as there are not large offsets that would prevent passage of the liner.

Procedures

Field studies were performed primarily in Hagerstown, Maryland, but some were also conducted in LaGrange Highlands, Illinois, and in 13 other North American sites. The field studies were supplemented with data gathered during the preparation of earlier reports on the Insituform process. These data were used to compare and evaluate various sewer rehabilitation techniques, considering parameters such as the effectiveness and durability of the product in eliminating infiltration, the procedures and problems associated with each rehabilitation option, the economic aspects of each option, and the sociological ramifications of each technique. Each rehabilitation alternative considered in this report has its place in the overall scheme of collection system renovation; hence defective segments of sewers must be considered individually, using the inspection tools available, to establish the best rehabilitation application for each instance

Potential Insituform users want to know how effective and durable the product is when exposed to a typical sewerage environment over an extended period. To answer this question, sites were visited where Insituform liners had been in place for a considerable time. Officials responsible for each installation were questioned about the need for the Insituform construction procedures, problems associated with the work, the effectiveness of the liner, and the durability of the repair material over time. Evaluations based on these visits are presented here with appropriate conclusions. This approach should enable prospective users to judge the feasibility of using Insituform liners in each circumstance.

Some attention must be paid to the problem of rehabilitating service laterals on private property without damaging the property. To eliminate infiltration from a sewer collection system, defective laterals must be rehabilitated as much as possible within cost constraints. Groundwater that repair work prevents from entering a mainline will seek out other avenues of entrance to the collection system, often migrating to deteriorated service lines or manholes.

Results and Conclusions

Sites Other Than Hagerstown

The site studies, interviews, and video tapes reviewed indicate that the Insituform method of sewer lining is a viable, cost-effective alternative for rehabilitation in various circumstances. Each situation must be considered individually to determine the appropriateness of the technique.

Sewers have been lined by the Insituform method in vastly different locations and geologies. Climatic conditions have varied from those in Winnipeg, Canada, in the middle of the winter to those in central Florida in the summer. Sewers transporting domestic-strength waste from municipalities and sewers carrying high-strength chemical wastes from industrial situations have been lined with the product and are holding up reasonably well under the conditions imposed on the liner.

The Insituform liner was chosen over other repair alternatives for a variety of reasons, but the deciding factor was generally the logistics of the site. Many industrial plants chose Insituform lining for sewers running under buildings. The cost in such cases was not only below that for other options, but the no-excavation procedure provided for minimal disruption of production during construction. Where the restoration costs of excavation were considerable or prohibitive (e.g., in built-up areas, areas with numerous services or land of great value), Insituform was found to be the most economical method of sewer rehabilitation. In some areas, the legal problems of gaining access to a site necessitated the use of Insituform because of its nondestructive and nondisruptive nature.

Since lining by Insituform takes much less time than conventional sliplining, situations in which lengthy construction cannot be tolerated lend themselves to this method. Sites favor Insituform when project staging areas are limited or when traffic control might cause problems; Insituform requires less equipment space and can easily be adapted to the remote location of installation and curing equipment.

The lining was implemented to eliminate either infiltration or exfiltration from sewer stretches, or to provide structural integrity to defective or severely deteriorated pipes. The parties interviewed generally agreed that the product was effective in performing this designated task. In three cases where weak spots and bubbles were detected in the post-rehabilitation television inspection before client acceptance, the lining was either removed and redone or a point repair was made.

Hagerstown Rehabilitation Study

1. For all mainline sewer rehabilitation techniques studied, effectiveness in eliminating infiltration depends directly on the rehabilitation of appurtenant facilities such as manholes, service laterals, etc.
2. The sanitary sewer rehabilitation program within any municipality must be an ongoing maintenance activity. Rehabilitated sewers, lift stations, manholes, etc., begin to deteriorate as soon as the repair is complete; this fact is evidenced by the gradual increase in wet weather flows seen at the treatment plant following completion of a collection system rehabilitation project.
3. Before-and-after flow data from this study revealed that test-and-seal, point repair, conventional sliplining, and Insituform lining were all successful in reducing the mainline infiltration of groundwaters.
4. The durability of each technique studied over the 3-year study period was very good. Specifically important was the apparent lack of deterioration in the point repairs and seal rehabilitations after 2 to 3 years. Recent discussions with the City of Hagerstown staff have indicated that a number of sections that received test-and-seal repairs were displaying a return of infiltrating groundwater. Plans are now in preparation to line these stretches with Insituform. During collection system rehabilitation, it was determined that some manhole sections in which grouting was planned could not be successfully sealed because of large voids or incompatible material in the sewer backfill. These sections were lined with Insituform after an analysis was made for cost effectiveness. City staff had indicated that much grouting performed in previous programs within Hagerstown had deteriorated to the point of ineffectiveness. In

many instances, these lines were successfully rehabilitated using Insituform in the recent program.

5. In some study sections lined with Insituform, flow data indicated the technique to be relatively ineffective in reducing infiltration. This result could have been due to either of the following causes:

   a. Groundwater may have been prevented from entering the collection system mains but mitigrated to deteriorated system elements such as services or manholes, where it eventually infiltrated.

   b. Tolerances associated with flow measuring equipment and methods may have resulted in data that were not totally representative. Numerous inconsistencies in the flow metering data strongly indicate that this item is the major contributing factor.

   Considering all data presented and the recent deterioration of grouting sections (not shown by flow data but determined by the City to be present), Insituform appears to be quite effective in eliminating the infiltration of groundwater from mainline sewers.

6. Though the Insituform manufacturer contends that the liner's smoothness and thinness provide the conduit with a greater hydraulic capacity than before repair, this result was not borne out in every test section.

7. The Insituform method of reinstating services without excavation is an excellent concept, but a development effort with respect to the Insitucutter is apparently necessary to render the system totally reliable. The Insitucutter is designed to be pulled through a sewer to cut a circular opening in the line at each service lateral.

8. Methods of lining service laterals without excavation are currently being developed by various lining firms, with some of the techniques appearing quite feasible.

9. Each repair technique has its advantages and problems. Individual applications should be considered, weighing costs versus benefits for each alternative at each site.

10. Initial construction cost figures indicate that the most cost-effective method of sewer system rehabilitation is a combination of point repair and test-and-seal, followed in order by conventional sliplining and Insituform lining. These rankings may change when we consider the life and serviceability of each alternative, especially in view of apparent problems Hagerstown has noted in test-and-seal work. In addition, it should be noted that the conventional lining project studies were very small compared with the Hagerstown Insituform work, with limited service reinstatement and surface restoration. In built-up areas with access problems, high restoration costs, and numerous service connections, Insituform lining would most likely be more economical than conventional lining. Each application must be analyzed individually.

Recommendations

Sites Other Than Hagerstown

A certain amount of follow-up study should be pursued in this case to establish the long-term effects of a potentially destructive environment on Insituform. Essentially, the sites visited in this report were lined within the past 5 years and might not be good examples of the far-reaching results of continued exposure to wastewater. Possibly some early Insituform installations in Europe might be studied.

The ongoing technical advances associated with this product should be monitored. Research is currently being performed on an advanced internal service-cutting system, and a technique is being developed for lining service laterals without excavation. As most of those involved with sewer rehabilitation will attest, extraneous flows will not be successfully eliminated from the sanitary sewer system until an acceptable, cost-effective means of rehabilitating sewer laterals is developed and refined.

The Insituform procedure is an advancement in the field of sewer rehabilitation. As such, it deserves a great deal of attention in the future.

Insufficient quality control was evidenced in three of these early installations, both in installation techniques and materials. Liner arrived at the site too long or too short, or with skin or seam imperfections that resulted in installation problems. Lack of preparation or attention to detail in the inversion and curing phases contributed to problems in the field. Preventive equipment maintenance should also receive a higher priority.

Hagerstown Rehabilitation Study

Insituform installers should pay careful attention to safety problems associated with their technique. The use of hot water under pressure to supply the resin-curing medium for this process deserves specific concern. This factor, coupled with the height at which the water is drawn from and discharged into the inversion tube, creates a very dangerous construction situation, especially during curing. Normal safety precautions should also be exercised with respect to construction scaffolding and work in enclosed areas.

The manufacturer should work to develop a reliable mechanical means of internally reinstating services in all sizes of sewers. The Insitucutter should be modified with this end in mind.

Finally, a detailed technical study should be conducted to establish the feasibility of rehabilitating sewer laterals in a cost-effective manner without excavating.

This report, prepared by Thomas I. Simmons and Associates, Rochelle, IL, was submitted by the City of Hagerstown, MD in fulfillment of CR 806625 under the partial sponsorship of the U.S. Environmental Protection Agency.

Michael R. Olson is with Thomas I. Simmons and Associates, Rochelle, IL 61068.
***Richard Field** is the EPA Project Officer (see below).*
The complete report, entitled "Insituform and Other Sewer Rehabilitation Techniques," (Order No. PB 86-130 192/AS; Cost: $16.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

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Project Summary

Alternative Sewer Studies

This report provides new design and operational information on two of the most effective and widely applied alternative sewer systems—small-diameter gravity and pressure sewers. The information provided here will help system designers and operators avoid or rectify problems resulting from sulfides and downhill hydraulics that could otherwise represent major impairments to the successful application of these technologies.

This Project Summary was developed by EPA's Water Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Small communities in need of new or expanded sanitary sewers are faced with a severe financial burden. Low population densities and unfavorable geological situations increase per capita costs of conventional sewers, which often account for up to 80% of the total capital costs of a new wastewater management system.

Conventional sewers are expensive. To insure that raw sewage flows freely, conventional sewer systems use large-diameter pipes set in the ground at minimum slopes. Pumping stations are often required as well. Extensive excavation is usually necessary to achieve the desired slopes. Flat terrain, high groundwater, and waterfront areas all add to construction costs and difficulties. Finally, infiltration and inflow (I&I) of extraneous water cannot be eliminated entirely in large pipes. The added wastewater volume and solids mean that the treatment plant must have a greater capacity than would be required to treat only the dry weather flow.

Alternative approaches to sewering that address some of the problems encountered with conventional systems can reduce collection and treatment costs. Three types of alternative sewers are discussed below:

- pressure sewers
- vacuum sewers
- small-diameter gravity (SDG) sewers

Discussion

Alternative sewers offer the dual advantages over conventional sewers of small-diameter pipes and a greater ability to follow the natural topography without risk of clogging, which reduces excavation and construction costs. Furthermore, all three of these sewers provide reduced I/I.

The two major types of pressure sewer systems are grinder pump (GP) and septic tank effluent pump (STEP). These two systems differ in the onsite equipment, layout, and quality of the wastewater conveyed to the pressure sewer. In GPs, solids are ground to a slurry and discharged through pressure lines. In STEPs, wastewater from a home first flows into a septic tank from which treated effluent is pumped to pressurized lines.

Vacuum sewers use a central vacuum source to constantly maintain a vacuum on small-diameter collection mains. Periodically, the pressure differential created by the vacuum source draws a slug of sewage from a holding tank at each home into the line. When sufficient volume of sewage is collected at a central vacuum station, it is pumped to the treatment plant or main interceptor.

Like the STEP system, a small-diameter gravity (SDG) sewer is used with individual septic tanks. Because solids are removed by the septic tank, pipes of 4 in. in diameter can be used at very shallow slopes without risk of clogging. The effluent requires little or no pumping, generally flowing by gravity to the treatment facility.

Despite their many advantages, several concerns have been raised about alternative sewers. The most important of these potential problems are:

- Excess sulfide generation, and
- Two-phase flow in pressure and SDG sewers

Sulfide generation affects all types of sewers. The problem manifests itself in unpleasant odors and corrosion produced by hydrogen sulfide. Years of experience have gone into the design of conventional sewer systems to minimize sulfide generation. Experience with sulfides in conventional sewer systems has raised two main concerns about alternative systems: (1) That the septic effluent in SDG and STEP systems may be more prone to sulfide generation, and (2) that the anaerobic nature of the pressure and the SDG sewers may contribute to sulfide generation.

Two-phase flow refers to a hydraulic problem of particular concern in pressure systems. In downhill sloping sections of pressure sewers, gas bubbles present in the pipeline can adversely affect flow. The typical solution is to install air-release valves at summits within the pipeline. However, in many cases this technique does not work efficiently, and additional steps must be taken to solve the problem.

Conclusions

Although a significant number of pressure and SDG sewers have been designed and constructed, there remain some significant gaps in understanding the technology. These studies provide some insights into two of the major technology gaps. The major conclusions are as follows:

1. GP systems can produce sulfides at a rate of three to four times that of STEP systems and about twice that of conventional sewer force mains because of the high organic strength of the wastewater.
2. STEP systems show unexplained losses of sulfide and gains in dissolved oxygen based on analyses performed in this study and previous data for septic tank effluents.
3. Both pressure systems (i.e., GP and STEP) can be expected to have some sulfide concentration in their wastewaters, with values varying from 1 to 14 mg/L based on this study.
4. GP sulfide concentrations will generally increase in the direction of mainline flow, but random locations of service lines and branches may mask this trend.
5. Concentrations of sulfides in pressure sewers cannot yet be quantifiably predicted because of the empirical nature of the available equations and their derivation from weaker conventional wastewaters.
6. SDG sewers should not be designed to minimize pipe sizes, to flow full for substantial periods, or to proliferate substantial inundated sections of mainline if sulfide minimization is desired.
7. For conventional gravity sewers, equilibrium sulfide concentrations result from long pipe segments of relatively uniform conditions. Applying the equilibrium equation for conventional gravity sewers to SDG sewers results in concentrations comparable with those observed in SDG sewers. These concentrations are much lower than the higher levels reported to occur in septic tanks.
8. Because of the phenomenon of conclusion No. 7, SDG sewers appear to be capable of producing terminal wastewater sulfide concentrations lower than those of pressure sewers.
9. Conventional placement of air-release valves at high points of a pressure sewer system does not preclude the entrainment of air, which results in headlosses greatly exceeding design calculations.
10. In downhill runs where the pressure main intersects the dynamic hydraulic grade line (HGL), a hydraulic jump is formed that generates gas bubbles that pass on to downstream segments of the main.
11. Placement of sewage-type automatic air-release valves at points at least 14 pipe diameters below hydraulic jump locations was effective in removing entrapped air and reducing headlosses to near theoretical levels.
12. Backpressure sustaining valves were found to be inadequate for control of downhill hydraulics in the pressure sewer because of high capital cost, intensive maintenance requirements, and unreliable operation.
13. On downhill runs with irregular terrain that provide numerous opportunities for the formation of smaller hydraulic jumps, standpipes were shown to be inexpensive and reliable The standpipes used large-diameter downlegs to prevent the escape and conveyance of air bubbles into the downstream segment of the mains and automatic air-release valves at their summits to expel the trapped gases.
14. Soil absorption beds were successfully used for the vented gases from the air-release valves to prevent hydrogen sulfide odors.

Recommendations

The designer needs improved capability to predict sulfide concentrations in pressure and SDG sewers. Toward this end, comprehensive studies of sulfides should be made from the septic tank to the terminus of a number of these systems to identify the gains and losses of sulfide concentration, to quantify the mechanisms responsible, and to develop predictive equations. Once this goal is accomplished, a study should be undertaken to develop a corrosion-based methodology for evaluating the alternatives of designing a transition station or modifying a receiving conventional sewer. Such a methodology would provide a quantitative solution to one of the major design obstacles in the design of pressure and SDG sewers that terminate at larger conventional sewers.

A need also exists for more quantitative assessment of the requirements for, location of, and design and operating and maintenance requirements for air-release valves in pressure and SDG sewer systems. Further assessment is also needed for soil absorption and other low-maintenance odor control methods appropriate for these alternative sewers.

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Urban Systems Research and Engineering, Inc., is located in Cambridge, MA 02138.

***James F. Kreissl** and **Robert P. G. Bowker** were the EPA Project Officers (see below).*

The complete report, entitled "Alternative Sewer Studies," (Order No. PB 86-131 224/AS; Cost: $9.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

*For further information, contact **James F. Kreissl** at:*

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